NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS ICE SURFACE TEMPERATURE (IST) EDR SOFTWARE (D39141 Rev A)

CDRL No. A032

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Revision/Change Record

Document Number D39141

Revision	Document Date	Revision/Change Description	Pages Affected
---	7-30-04	Initial Release.	All
A1	11-30-04	Reflects Science To Operational Code Conversion.	All
A2	3-22-05	Inserted Unit Test Procedure/Results.	Pgs 17-31
A3	4-27-05	Reflects NGST comment corrections plus updated upper right header date, title/signature page dates, Revision/Change Record.	All
A4	7-01-05	Removed export markings per 26May05 official policy change and under Section 1.3.3, Source Code and Test Data References, inserted a more detailed table listing paths to find applicable source code within the ClearCase configuration management tool.	All
A5	7-11-05	Per a Justin Ip request, changed Table 2.2-6, Pg 9, Byte 2, Bit 5, to read “AOT condition (550 nm)” versus previous wording “AOT condition (M11)”.	Pg 9
A6	7-13-05	Per a Dan Antzoulatos 11Jul05 comment, reworded the table under Section 1.3.3 defining a path on ClearCase to find applicable source code.	Pg 2
A7	10-05-06	Updated OAD for EDRPR quality flag changes.	All
A8	1-29-07	New logo, cleanup grammar, etc.	All
A9	8-02-07	New Document number. TMs NP-EMD.2005.510.0005, NP-EMD.2006.510.0012 & NP-EMD-2006.510.0081 have been implemented in B1.5. Delivered to NGST.	All
A10	11-30-07	Updated OAD for EDRPR/CDFCB-X quality flag changes.	All
A11	9-12-08	Reformatted document to implement template D41851 format. Modified graceful degradation and DQN sections. New cover sheet, update references, acronym list, prepare for peer review. Delivered to NGST. Accept all changes after delivery.	All
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A	3-18-09	Incorporated TIM comments and prepared for final ARB/ACCB delivery. Incorporates ECR A-217. Approved for Public Release per Contracts Letter 100610-02.	All

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1.0 INTRODUCTION

1.1 Objective

The purpose of the Operational Algorithm Description (OAD) document is to express, in computer-science terms, the remote sensing algorithms that produce the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

The science basis of an algorithm is described in a corresponding Algorithm Theoretical Basis Document (ATBD). The OAD provides a software description of that science as implemented in the operational ground system --- the Data Processing Element (DPE).

The purpose of an OAD is two-fold:

1. Provide initial implementation design guidance to the operational software developer
2. Capture the “as-built” operational implementation of the algorithm reflecting any changes needed to meet operational performance/design requirements

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents.

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm(s) required to create the VIIRS Ice Surface Temperature EDR. The theoretical basis for this algorithm is described in Section 3.3 of Ice Surface Temperature (IST) Visible/Infrared Imager/Radiometer Suite (VIIRS) Algorithm Theoretical Basis Document (ATBD), D43761.

1.3 References

The primary software detailed design documents listed here include science software documents, NPOESS program documents, plus source code and test data references.

1.3.1 Document References

The science and system engineering documents relevant to the algorithms described in this OAD are listed in Table 1.

Table 1: Reference Documents

Document Title	Document Number/Revision	Revision Date
Ice Surface Temperature: Visible/Infrared Imager/Radiometer Suite Algorithm Theoretical Basis Document	D43761 Rev. A	31 July 2008
VIIRS Surface Temperature Module Level Software Architecture	Y2473 Ver. 5 Rev. 12	30 July 2004
VIIRS Surface Temperature Module-Level Interface Control Document	Y3281 Ver. 5 Rev. 4	Dec 2003
VIIRS Surface Temperature Module Level Data Dictionary	Y0011652 Ver. 5 Rev. 3	Dec 2003
VIIRS Ice Surface Temperature Unit Level Detailed Design	Y2503 Ver. 5.1 Rev. 5	30 July 2004
VIIRS Radiometric Calibration Unit Level Detailed Design	Y2490 Ver. 5 Rev. 4	30 Sep 2004
Operational Algorithm Description Document for the VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (CAL) SDR	D41868 Rev. A11	22 Feb 2008
Operational Algorithm Description Document for the VIIRS Cloud Mask Intermediate Product (VCM IP) Software	D36816 Rev. A11	17 Oct 2008

Document Title	Document Number/Revision	Revision Date
VIIRS Ice Surface Temperature EDR Science Grade Software Unit Test Document	D32139 Rev. ---	30 July 2004
VIIRS Sea Ice Concentration Intermediate Product (IP) OAD	D42820 Rev A6	3 Nov 2008
Operational Algorithm Description Document for VIIRS Aerosol Products (AOT, APSP & SM) IP/EDR	D39292 Rev. B10	12 Sep 2008
NPP EDR Production Report	D37005 Rev. C	16 Mar 2007
EDR Interdependency Report	D36385 Rev. D	18 Jun 2008
NPP Mission Data Format Control Book (MDFCB)	CCR Form_429--9-02-131 Rev B	04 Apr 2006
CDFCB-X Volume I - Overview	D34862-01 Rev. C	11 Jul 2008
CDFCB-X Volume II – RDR Formats	D34862-02 Rev. B	27 Aug 2007
CDFCB-X Volume III – SDR/TDR Formats	D34862-03 Rev. B	11 Jul 2008
CDFCB-X Volume IV Part 1 – IP/ARP/GEO Formats	D34862-04-01 Rev. B	07 Jul 2008
CDFCB-X Volume IV Part 2 – Atmospheric, Clouds, and Imagery EDRs	D34862-04-02 Rev. B	07 Jul 2008
CDFCB-X Volume IV Part 3 – Land and Ocean/Water EDRs	D34862-04-03 Rev. B	07 Jul 2008
CDFCB-X Volume IV Part 4 – Earth Radiation Budget EDRs	D34862-04-04 Rev. B	07 Jul 2008
CDFCB-X Volume V - Metadata	D34862-05 Rev. C	27 Jun 2008
CDFCB-X Volume VI – Ancillary Data, AuxiliaryData, Reports, and Messages	D34862-06 Rev. F	30 Jan 2009
CDFCB-X Volume VII – NPOESS Downlink Formats	D34862-07 Rev. ---	03 Jul 2008
CDFCB-X Volume VIII – Look Up Table Formats	D34862-08 Rev. ---	02 Jul 2008
NPP Command and Telemetry (C&T) Handbook	D568423 Rev. C	30 Sep 2008
VIIRS Science Algorithms 2.6 Delivery to IDPS Package Version Description	D32137 Rev. ---	30 July 2004
Data Processor Inter-subsystem Interface Control Document (DPIS ICD)	D35850 Rev V	11 Feb 09
Processing SI Common IO Design Document	DD60822-IDP-011 Rev. A	21 June 2007
D35836_G_NPOESS_Glossary	D35836_G Rev. G	10 Sep 2008
D35838_G_NPOESS_Acronyms	D35838_G Rev. G	10 Sep 2008
NGST/SE technical memo – IST OAD Update	NP-EMD.2005.510.0005	11 Jan 2005
NGST/SE technical memo – NPP_VIIRS_IST_QFFillValues_SPCR_ALG972	NP-EMD.2006.510.0012	30 Jan 2006
NGST/SE technical memo – NPP_VIIRS_IST_LST_STIP_BugsFix	NP-EMD.2006.510.0081	31 Oct 2006
NGST/SE technical memo – NPP_IST_ThinCirrusFlag_Updates	NP-EMD.2007.510.0055	9 Sep 2007

1.3.2 Source Code References

The science and operational code and associated documentation relevant to the algorithms described in this OAD are listed in Table 2.

Table 2: Source Code References

Reference Title	Reference Tag/Version	Revision Date
VIIRS IST Science-grade Software	Rev. 1.02	Jan 2006
VIIRS IST Operational Software	B1.5	July 2007
NGST/SE Technical Memo – NPP_VIIRS_IST_QFFillValues_SPCR_ALG972	NP-EMD.2006.510.0012	Jan 2006
NGST/SE Technical Memo – NPP_VIIRS_IST_LST_STIP_BugsFix	NP-EMD.2006.510.0081	Oct 2006
NGST/SE Technical Memo – NPP_IST_ThinCirrusFlag_Updates	NP-EMD.2007.510.0055	Sep 2007
OAD – VIIRS IST EDR Rev A	Build 1.5.x.1 (PCR 019285) and Build Post-X-B (PCR019679)	1-12-09 and 3-09-09

2.0 ALGORITHM OVERVIEW

The purpose of the IST Module is to retrieve the IST for each cloud-free land pixel at VIIRS moderate-resolution. Brightness Temperature data from the VIIRS SDR, VIIRS Aerosol Optical Thickness (AOT) Intermediate Product (IP), VIIRS Cloud Mask (VCM) IP, and Ice Concentration IP are used to decide whether the pixel is processed and whether a 2-band split window baseline algorithm or a single-band split window fallback algorithm is used. The IST is retrieved using a regression equation with separate coefficients for day and night retrievals. The calculated Ice Surface Temperature and Quality Flag bytes are written to the VIIRS IST EDR. The IST processing chain is shown in Figure 1.

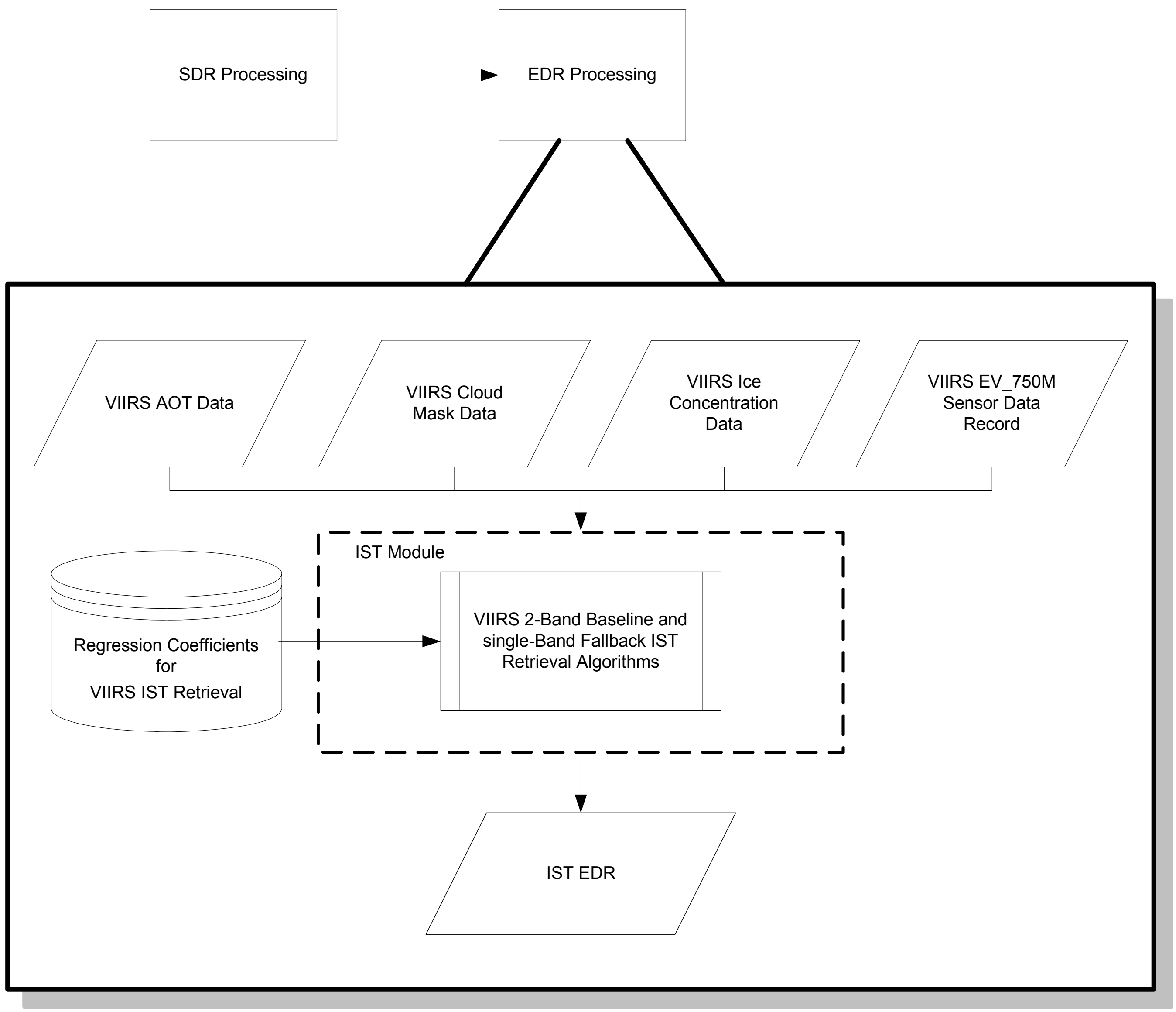

Figure 1: IST Processing Chain

2.1 Ice Surface Temperature EDR Description

The IST retrieval algorithm and its theoretical basis are described in detail within the VIIRS IST Algorithm Theoretical Basis Document (ATBD), D43761.

2.1.1 Interfaces

The IST algorithm is initiated by the Infrastructure (INF) Software Item (SI) to begin processing the data. The INF SI provides tasking information to the algorithm indicating which granule is to be processed. The Data Management System (DMS) SI provides data storage and retrieval capability. The interface to these SIs is implemented by a library of C++ classes. The IPO Model interface to INF and DMS is shown in Figure 2.

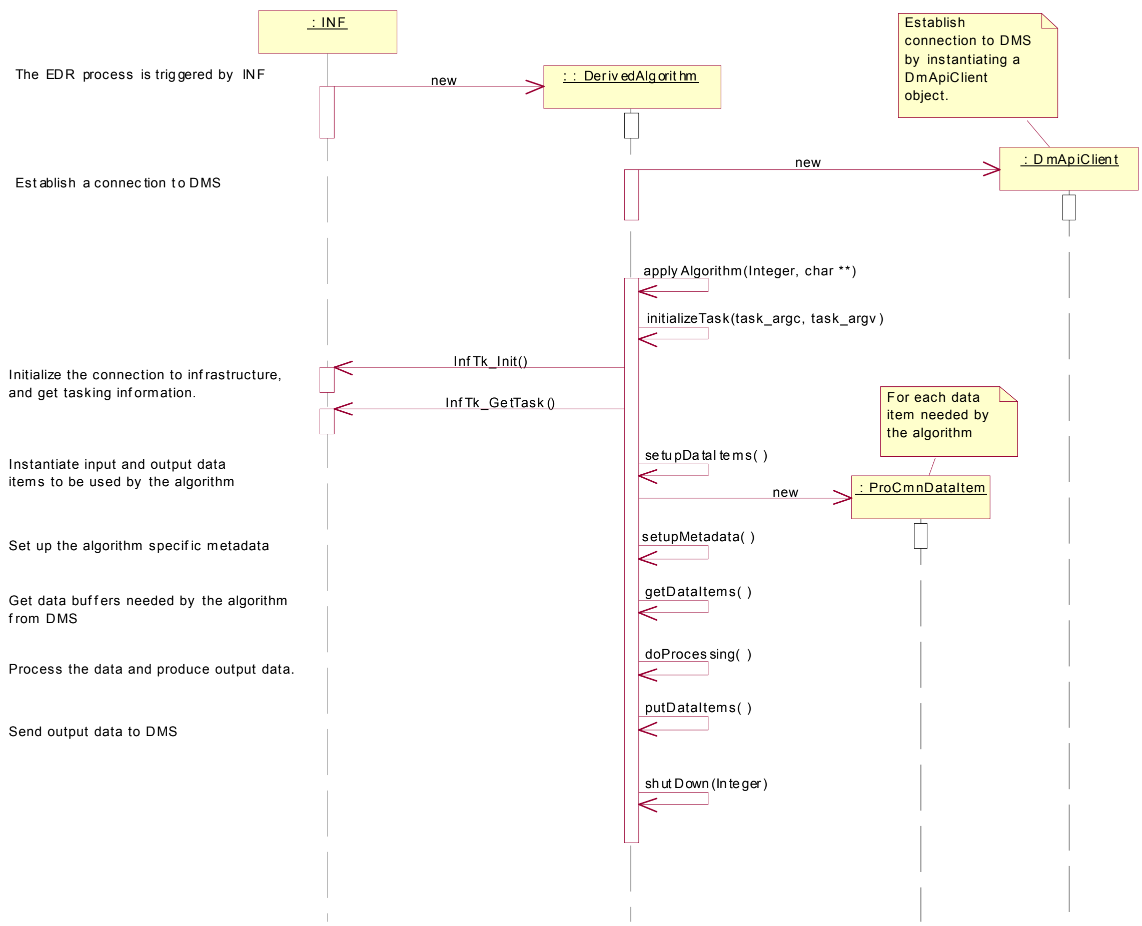

Figure 2: IPO Model Interface to INF and DMS

2.1.1.1 Inputs

Table 3 through Table 8 show the IST EDR inputs. Refer to the CDFCB-X Volume VI, Appendix C, D34862, for a detailed description of the inputs.

Table 3: IST EDR Module - Main Inputs

Input	Type	Description/Source	Units/Valid Range
IST EDR DQTT	IngMsdThresholds_DQTT	Data quality threshold table provided by the ING subsystem (Optional input)	Percent / 0 to 100 Please refer to CDFCB-X Volume VI Appendix C

Input	Type	Description/Source	Units/Valid Range
BT_M15	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Brightness Temperature of Band M15/ VIIRS 750 m resolution SDR	Kelvin / 180 K < BT_{M15} < 350 K Please refer to VIIRS Radiometric Calibration ATBD
BT_M16	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Brightness Temperature of Band M16/ VIIRS 750 m resolution SDR	Kelvin / 180 K < BT_{M16} < 350 K Please refer to VIIRS Radiometric Calibration ATBD
SolZenAng	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Solar Zenith Angle/ VIIRS 750 m resolution SDR	Radians/ 0 to $\pi/2$
SenZenAng	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Sensor Zenith Angle/ VIIRS 750 m resolution SDR	Radians/ 0 to $\pi/2$
Latitude	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Latitude/ VIIRS 750 m resolution SDR	Radians/ $-\pi/2$ to $\pi/2$
act_scans	Int	Actual number of scans in granule	Unitless / 0 - 48

Table 4: IST EDR Module - Main Inputs (VCM)

Input	Type	Description/Source	Units/Valid Range
CM Confidence	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Cloud Confidence Indicator/ VIIRS Cloud Mask IP	11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confident Clear
Land/Water	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Land/Water Background/ VIIRS Cloud Mask IP	000 = Land & Desert 001 = Land no Desert 010 = Inland Water 011 = Sea Water 101 = Coastal
Cloud Adjacency	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Adjacent Pixel Cloud Confidence Value/ VIIRS Cloud Mask IP	11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confident Clear
Sun Glint	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Sun Glint/ VIIRS Cloud Mask IP	00 = None 01 = Geometry Based 10 = Wind Speed Based 11 = Geometry & Wind
Thin Cirrus	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Thin Cirrus Detection / VIIRS Cloud Mask IP	1 = Thin Cirrus 0 = No Thin Cirrus
Day/Night	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Day/Night / VIIRS Cloud Mask IP	1 = Day 0 = Night
SnowIce	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Snow/Ice / VIIRS Cloud Mask IP	1 = Snow 0 = No Snow
Shadow	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Shadow / VIIRS Cloud Mask IP	1 = Shadow 0 = No Shadow
Fire	UInt*8 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Fire / VIIRS Cloud Mask IP	1 = Fire 0 = No Fire

Table 5: IST EDR Module - Main Inputs (Ice Concentration IP)

Input	Type	Description/Source	Units/Valid Range
Ice Weight	Float*32 x [I_VIIRS_SDR_ROWS x I_VIIRS_SDR_COLS]	Ice Weight / VIIRS Ice Concentration IP	Unitless / 0.0 to 1.0

Input	Type	Description/Source	Units/Valid Range
Ice Fraction	Float*32 x [I_VIIRS_SDR_ROWS x I_VIIRS_SDR_COLS]	Ice Fraction/ VIIRS Ice Concentration IP	Unitless / 0.0 to 1.0

Table 6: IST EDR Module - Main Inputs (AOT IP)

Input	Type	Description/Source	Units/Valid Range
Aerosol Optical Thickness	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	AOT @ 550 nm (slant path) VIIRS AOT IP	Unitless / AOT_550 ≥ 0.0, and –999.9 (filled value)

Table 7: IST EDR Module – Ancillary Data Inputs

Input	Type	Description/Source	Units/Valid Range
Configurable Parameters	See Table 15 for List of Tunable Algorithm Parameters	Ingest (ING)	See Table 15 for List of Tunable Algorithm Parameters

Table 8: IST LUT Data

Input	Type	Description/Source	Units/Valid Range
Ist Coeffs	Float*32 x [term][day/night][algorithm][regime]	IST Regression Coefficients LUT / IST LUT data	Unitless

2.1.1.2 Outputs

The Ice Surface Temperature EDR produces a scaled output product. Primary outputs of the IST EDR scaled products can be found in Table 9. Primary outputs of the IST EDR non-scaled products can be found in Table 10. Refer to the CDFCB-X, D34862, for a detailed description of the outputs.

Table 9: Contents of the IST Output - Scaled Version

Output	Data Type/size	Description	Units/Valid Range
IST	UInt*16 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Scaled representation of IST for each pixel in the granule.	Kelvin / 155.0 to 275.0
IST EDR Quality Flags	UInt*8 x 3 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Ice Surface Temperature Quality Flags for each VIIRS pixel. See Table 11 for details.	N/A
IST Scale	Float*32	The scale value for the Ice Surface Temperature. This can be found by subtracting the minimum acceptable IST temperature of 155 K from the maximum of 275 K and dividing this result by 65000. The maximum and minimum temperatures are configurable.	Unitless
IST Offset	Float*32	The offset value is the minimum acceptable temperature of the IST. The minimum temperature is 155 K and it is configurable.	Unitless

Table 10: Contents of the IST Output - Non-scaled Version

Output	Data Type/size	Description	Units/Valid Range

Output	Data Type/size	Description	Units/Valid Range
IST	Float*32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Scaled representation of IST for each pixel in the granule.	Kelvin / 155.0 to 275.0
IST EDR Quality Flags	UInt*8 x 3 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Ice Surface Temperature Quality Flags for each VIIRS pixel. See Table 11 for details.	N/A

Table 11: QF Output Bits and Descriptions

BYTE	Bit	Flag Description Key	Result
0	0-1	IST Quality	Bit 1 Bit 0 0 0 = High 0 1 = Medium 1 0 = Low 1 1 = No Retrieval
	2	Algorithm	0 = 2-band split window baseline 1 = Single-band (12 μm) fallback
	3	Day/Night	0 = Night, (85^o < Solar Zenith Angle) 1 = Day, (0^o ≤ Solar Zenith Angle ≤ 85^o)
	4	Band M15 Brightness Temperature Range	0 = Within range, (180 K < BT_{M15} < 350 K) 1 = Out of range
	5	Band M16 Brightness Temperature Range	0 = Within range, (180 K < BT_{M16} < 350 K) 1 = Out of range
	6	Active Fire	0 = No active fire 1 = Active fire
	7	Pixel Ice Zone	0 = Within the expected Ice Coverage zone 1 = Outside the expected Ice Coverage Zone (Pixel is South of 36N and North of 50S latitude)
1	0-1	Ice Fraction	Bit 1 Bit 0 0 0 for Ice fraction = 1.00 0 1 for 0.95 ≤ ice fraction < 1.00 1 0 for 0.00 < ice fraction < 0.95 1 1 for Ice fraction ≤ 0.00
	2-3	Cloud Confidence Indicator	Bit 1 Bit 0 0 0 = Confidently Clear 0 1 = Probably Clear 1 0 = Probably Cloudy 1 1 = Confidently Cloudy
	4-5	Adjacent Pixel Cloud Confidence Indicator	Bit 1 Bit 0 0 0 = Confidently Clear 0 1 = Probably Clear 1 0 = Probably Cloudy 1 1 = Confidently Cloudy
	6	Thin Cirrus	0 = No Thin Cirrus 1 = Thin Cirrus
	7	Spare Bit	Initialized to 0

BYTE	Bit	Flag Description Key	Result
2	0-2	Land/Water Background	Bit 2 Bit 1 Bit 0 0 0 0 = Land and Desert 0 0 1 = Land / No Desert 0 1 0 = Inland Water 0 1 1 = Sea Water 1 0 1 = Coastal
	3	Snow / Ice Surface	0 = No snow / ice 1 = Snow / ice
	4	Shadow Detected	0 = No 1 = Yes
	5	AOT Condition (550 nm, slant path)	0 = within range, (AOT ≤ 1.0) 1 = outside range
	6	Expected IST range	0 = Within the expected IST range (213 K ≤ IST ≤ 275 K) 1 = Outside the expected IST range
	7	Spare Bit	Initialized to 0

2.1.2 Algorithm Processing

The IST EDR code is written in C but uses a C++ compiler to facilitate interfaces with the IDPS Infrastructure (INF) and Data Management Subsystem (DMS). The objective of the IST algorithm is to calculate IST at each pixel in a moderate resolution (750 m) granule with all the available input. Two similar regression algorithms are used to perform this retrieval:

1) a baseline 2-band split window algorithm which uses the brightness temperature from a pair of VIIRS wavebands in the Long-Wavelength Infrared (LWIR) atmospheric window (Bands M15 and M16), and
2) a fallback single-band algorithm where only the LWIR band M16 is used.

Quality assessment flags for each pixel are stored in the IST Flag output.

2.1.2.1 Main Module – ist.cpp

The ist.cpp routine is the main driver. It calls the following subroutines: ProCmnVcm_Extractor(), AggregateIce(), and RetrieveIst().

2.1.2.2 ProCmnVcmExtractor( )

This derived function extracts information from the VCM IP to help define the processing path. In addition to cloud cover assessment, the VCM IP provides information on land/water, snow/ice, day/night, shadow, thin cirrus, and active fires.

2.1.2.3 AggregateIce( )

This subroutine aggregates imagery resolution ice concentration data to determine if ice is present within the moderate resolution pixels. This function does not process any moderate pixel that has an imagery pixel with zero weight and only aggregate pixels with all positive non-zero weights. Weight information comes from the ice weight input.

2.1.2.4 RetrieveIst( )

The logic flow of the IST retrieval algorithm is provided in **Error! Reference source not found.**. The core logic occurs in two functions, setIstQualFlags()and calculateIst(). In the current implementation, IST QFs additionally serve as decision flags. Their values are used in the decision of whether IST can be retrieved and, if so, which algorithm to use.

IST is not retrieved if any of the following conditions occur:

- band M16 Brightness Temperature is outside the sensor specification defined range, or
- the pixel is not Ice, or
- the pixel is confident cloudy (i.e., VCM Cloud Confidence Flag indicates "Confidently Cloudy"), or
- the pixel is not snow/ice

These pixels are filled with NA_FLOAT32_FILL and marked with an IST QF of "No Retrieval".

For processed pixels, IST is retrieved by either the baseline 2-band split window algorithm or the single-band fallback algorithm. In general, the 2-band split window algorithm is used under optimal conditions: ice covered pixel, no active fires, and "in-range" brightness temperatures for the M15 and M16 bands. Otherwise, the single-band fallback algorithm is used. The logic to determine which algorithm is used is provided in Table 12.

Equations for the 2-band split window and single-band algorithms are specified in Table 13. The implementation is presented in calculateIst(). Daytime and nighttime retrievals are identical except that a different set of regression coefficients is used in the look-up table (LUT).

For an off-nominal condition where an IST is retrieved that is outside of the determined range, the IST field is filled with ERR_FLOAT32_FILL and the IST quality bit field is set to "No Retrieval".

The AOT values from the VIIRS AOT IP at 550 nm band (slant path) are used for AOT exclusion.

2.1.2.5 IST QF Logic

IST Flags consist of three 8-bit words as shown in Table 11. The logic to set these flags is performed in function `setIstQualFlags()` and is provided in Table 12.

The overall quality of the IST pixel is represented by the quality bit field. Pixel quality is flagged as "No Retrieval" when the following applies:

- (BT_M16 is outside range) or (Pixel is outside horizontal ice coverage zone) or (Cloud Confidence is "Confidently Cloudy") or (Pixel is not Ice) or (Pixel is not snow/ice)
- IST <= 0 (Determined after attempt is made to retrieve IST).

Pixel quality is flagged as follows given the applicable conditions:

- (BT_M15 and BT_M16 are inside range) and (Pixel is no Fire) and (Pixel is snow/ice) and (Pixel is no Thin Cirrus)
  - (Pixel is no AOT exclusion) and (Pixel is Day)
    - (Cloud Confidence is "Confidently Clear") and (Pixel is Ice)
      - IST Quality = "High Quality"
    - ((Cloud Confidence is "Confidently Clear) or (Cloud Confidence is "Probably Clear")) and (Pixel is "Primarily Ice")
      - IST Quality = "Medium Quality"
    - ((Cloud Confidence is not "Confidently Clear") and (Cloud Confidence is not "Probably Clear")) or ((Pixel is not Ice) and (Pixel is not "Primarily Ice"))
      - IST Quality = "Low Quality"
  - (Pixel is no AOT Exclusion) and (Pixel is not Day)

        - ((Pixel is Ice) or (Pixel is "Primarily Ice")) and ((Cloud Confidence is "Confidently Clear") or (Cloud Confidence is "Probably Clear"))
            - IST Quality = "Medium Quality"
        - ((Cloud Confidence is not "Confidently Clear") and (Cloud Confidence is not "Probably Clear")) or ((Pixel is not Ice) and (Pixel is not "Primarily Ice"))
            - IST Quality = "Low Quality"
    - (Pixel is AOT Exclusion) and (Pixel is not Day)
        - IST Quality = "Low Quality"
- (BTM15 is outside range) or (Pixel is Fire) or (Pixel is Thin Cirrus)
    - IST Quality = "Low Quality"

2.1.2.6 IST LUT Coefficient Selection

A unique set of regression coefficients is derived offline for IST. Each IST equation found in Table 13 uses a different set of coefficients for a given day/night condition. Access to the coefficients is achieved by setting index values based on the given pixel viewing conditions and indicating which algorithm approach to use. Once indices are specified, coefficients are retrieved for the desired IST algorithm by indexing on the "term" index. Currently, the "regime" index should be set to "0" and has only one value. It is a placeholder for possible future improvement by further stratification of atmospheric conditions. For the 2-band split window algorithm, there are four coefficients. For the single-band fallback algorithm, there are three coefficients. For the latter, an additional zero-valued coefficient is present as "filler" in the LUT.
.
Example:

LUTCoeffs[n][1][0][0], where n is indexed from 0 to 3, corresponds to the coefficients a_0 to a_3 of the 2-band split window algorithm under daytime viewing conditions.

Figure 3: IST Retrieval Logic Flow

Table 12: IST QF Logic

IST Flag	Input Source	Flag Setting

Horizontal Ice Coverage zone	VIIRS Earth View 750-meter SDR	if (36^o ≤ Latitude ≤ 90^o or –90^o ≤ Latitude ≤ -50^o)
		set to "within ice coverage zone"
		otherwise
		set to "outside ice coverage zone"
		end if

Snow/Ice Surface	VCM IP/Snow/Ice Flag	IST Snow/Ice Flag = VCM Snow/Ice Flag

Band M15 Brightness Temperature Quality	VIIRS Earth View 750-meter SDR	if (180 K < BT_{M15} < 350 K)
		set to "within range"
		otherwise
		set to "out of range"
		end if

Band M16 Brightness Temperature Quality	VIIRS Earth View 750-meter SDR	if (180 K < BT_{M16} < 350 K)
		set to "within range"
		otherwise
		set to "out of range"
		end if

AOT Condition (VIIRS 550 nm band, slant path)	VIIRS AOT IP	if (AOT ≤ 1.0)
		set to "within range"
		otherwise
		set to "out of range"
		end if

Day/Night	VIIRS Earth View 750-meter SDR	if (0^o ≤ Solar Zenith Angle ≤ 85^o)
		set to "Day"
		otherwise
		set to "Night"
		end if

Shadow Detected	VCM IP / Shadow Flag	IST Shadow Flag = VCM Shadow Flag
Thin Cirrus	VCM IP / Thin Cirrus Flag	IST Thin Cirrus Flag = VCM Thin Cirrus Flag
Fire	VCM IP / Fire Flag	IST Fire Flag = VCM Fire Flag
Cloud Confidence Indicator	VCM IP / Cloud Detection and Confidence Indicator	IST Cloud Confidence Indicator = VCM Cloud Confidence Indicator
Adjacent Pixel Cloud Confidence Indicator	VCM IP / Adjacent Pixel Cloud Confidence Indicator	IST Cloud Confidence Indicator = VCM Adjacent Pixel Cloud Confidence Indicator
Land/Water	VCM IP / LandWater Flag	IST LandWater = VCM LandWater flag

Ice Fraction	VIIRS Ice Concentration IP / Ice Fraction	if (Ice Fraction = 1.00)
		set to "Ice"
		else if (0.95 ≤ Ice Fraction < 1.00)
		set to "Primarily Ice"
		else if (0.00 < Ice Fraction < 0.95)
		set to "Ice-Water Mix"
		otherwise
		set to "Not Ice"
		end if

Algorithm	Logical combination of IST Flags	if (BT_{M15} is "within range") and
		(BT_{M16} is "within range")
		set to "2-Band"
		otherwise
		set to "1-Band"
		end if

Quality	Logical combination of IST Flags	See Section 2.1.2.5
Out of range	Computed in algorithm	Set to IST_OUTSIDE if IST values are greater than max allowable IST temp or less than min allowable IST temp

IST Flag	Input Source	Flag Setting
Exclusion Summary	Logical combination of IST and cloud mask computations and inputs.	Currently set to the value of the AOT exclusion flag

Table 13: IST Core Equations

VIIRS IST baseline split window algorithm
Daytime:
$IST = a_0 + a_1 T_{M15} + a_2(T_{M15} - T_{M16}) + a_3(\sec\theta - 1)$
Nighttime:
$IST = b_0 + b_1 T_{M15} + b_2(T_{M15} - T_{M16}) + b_3(\sec\theta - 1)$
VIIRS IST fallback single-band algorithm
Daytime:
$IST = a_0 + a_1 T_{M16} + a_2(\sec\theta - 1)$
Nighttime:
$IST = b_0 + b_1 T_{M16} + b_2(\sec\theta - 1)$
where • IST is the retrieved ice surface temperature, • a_n and b_n are coefficients in the IST LUT and are dependent on day/night conditions, • θ is the sensor zenith angle, • T_{M15} and T_{M16} are the brightness temperatures at VIIRS bands M15 and M16 respectively. The equations above correspond to the IST ATBD, D43761, Section 3.3.2.1, Equations (10) and (11) with minor modifications.

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There are two cases where input graceful degradation in indicated in the Ice Surface Temperature EDR

1. The primary input denoted in the algorithm configuration guide cannot be successfully retrieved but an alternate input can be retrieved

2. Graceful degradation is indicated if an input retrieved for the algorithm has its N_Graceful_Degradation metadata field set to YES (propagation).

Table 14 details the instances of this case for IST. Note that the shaded cells indicate that the graceful degradation was done upstream at product production.

Table 14: IST Graceful Degradation

Input data description	Satellite	Baseline data source	Primary backup data source	Secondary backup data source	Tertiary backup data source	Graceful degradation done upstream
Aerosol Optical Thickness	NPP,PM1, TR1	VIIRS_GD_15.4.1 VIIRS AOT IP	VIIRS_GD_25.4.1 NAAPS	VIIRS_GD_15.4.1 Climatology	N/A	Yes, backup only.

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

When IST cannot be retrieved due to conditions such as invalid SDR data, cloudy pixel, non-Ice pixel, and BT_M16 out of range, IST pixel values are set to ERR_FLOAT32_FILL. The IST QFs are unaffected by this condition and should still be set as they provide information on why IST was not retrieved successfully.

2.1.5 Data Quality Monitoring

Each algorithm uses specific criteria contained in a Data Quality Threshold Table (DQTT) to determine when a Data Quality Notification (DQN) is produced. The DQTT contains the threshold used to trigger the DQN as well as the text contained in the DQN. If a threshold is met, the algorithm stores a DQN in DMS indicating the test(s) that failed and the value of the DQN attribute. For more algorithm specific detail refer to the CDFCB-X, D34862.

2.1.6 Computational Precision Requirements

The NPP VIIRS IST EDR requires accuracy and precision on the order of tenths of degrees. Input data used meets this degree of precision requirement. Regression equations are executed using a combination of 32-bit floating-point precision values.

2.1.7 Algorithm Support Considerations

Table 15 shows a list of algorithm configurable parameters with their descriptions, plus a column of current or future assigned values.

Table 15: List of Algorithm Configurable Parameters

Algorithm Parameter	Description	Assigned Values
min_Bt_M15	Minimum brightness temperature for M15	180 K
max_Bt_M15	Maximum brightness temperature for M15	350 K
min_Bt_M16	Minimum brightness temperature for M16	180 K
max_Bt_M16	Maximum brightness temperature for M16	350 K
ice_Threshold	Ice fraction threshold for “ICE”	1.00
max_SolZen_Lim	Solar zenith angle defining day/night boundary	85^{o} * DEG2RAD
ice_Primary_Threshold	Ice fraction threshold for “PRIMARILY ICE”	0.95
ice_No_Threshold	Ice fraction threshold for “NOT ICE”	0.00
min_Aot_Lim	Minimum AOT value	0.0
max__Aot_Lim	Maximum AOT value	1.0
min_Ist_Temp	Minimum IST measurement range	213 K
max_Ist_Temp	Maximum IST measurement range	275 K
ist_Min_IceCov_Lat_N	Minimum latitude of horizontal ice coverage zone	36^{o} * DEG2RAD
ist_Max_IceCov_Lat_S	Maximum latitude of horizontal ice coverage zone	-50^{o} * DEG2RAD

2.1.8 Assumptions and Limitations

2.1.8.1 Assumptions

The IST retrieval algorithm assumes VIIRS M15 SDR, VIIRS M16 SDR, VCM IP, VIIRS Ice Concentration, and VIIRS AOT IP are available before processing.

2.1.8.2 Limitations

The IST EDR is retrieved under clear conditions with known ice type classification and valid brightness temperature from at least the VIIRS M16 band.

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

The current glossary for the NPOESS program, D35836_E_NPOESS_Glossary, can be found on eRooms. Table 16 contains those terms most applicable for this OAD.

Table 16: Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of: 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Configuration Control Board (ACCB)	Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.). *[Supplementary Definition]* An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT.
Operational-Grade Software	Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code.

Term	Description
Raw Data Record (RDR)	*[IORD Definition]* Full resolution digital sensor data, time referenced and earth located, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression. *[Supplementary Definition]* A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use.
Retrieval Algorithm	A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing.
Science Algorithm	The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade".
Science Algorithm Provider	Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.
Science-Grade Software	Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure.
SDR/TDR Algorithm	Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Sensor Data Record (SDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data. *[Supplementary Definition]* A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data.

Term	Description
Temperature Data Record (TDR)	*[IORD Definition]* Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. *[Supplementary Definition]* A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.

3.2 Acronyms

The current acronym list for the NPOESS program, D35838_E_NPOESS_Acronyms, can be found on eRooms. Table 17 contains those terms most applicable for this OAD.

Table 17: Acronyms

Acronym	Description
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
CAL	Calibration
CDFCB-X	Common Data Format Control Book - External
DMS	Data Management Subsystem
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
DQTT	Data Quality Test Table
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
IST	Ice Surface Temperature
LUT	Look-Up Table
MDFCB	Mission Data Format Control Book
QF	Quality Flag
SDR	Sensor Data Record
SI	International System of Units
TBD	To Be Determined
TBR	To Be Resolved
VCM	VIIRS Cloud Mask

4.0 OPEN ISSUES

Table 18: List of OAD TBD/TBRs

No.	DESCRIPTION	Resolution Date
None		